LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

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Diesel Engine Lubrication

The Influence of Construction on Choice of Lubricants

IT is impossible today to hold back or even retard the phenomenal progress of the Diesel engine. The present era of modern industrial machinery development has seen the Diesel engine (frequently termed "oil engine") advance in the past decade to a place of prominence in the generation of power. In its rapid development it has not only covered the field of central power stations, where this type of engine offers an ideal solution of many peak load and standby problems, but it has also shown itself in particular to be a revolutionary improvement for propelling the merchant fleets of the world.

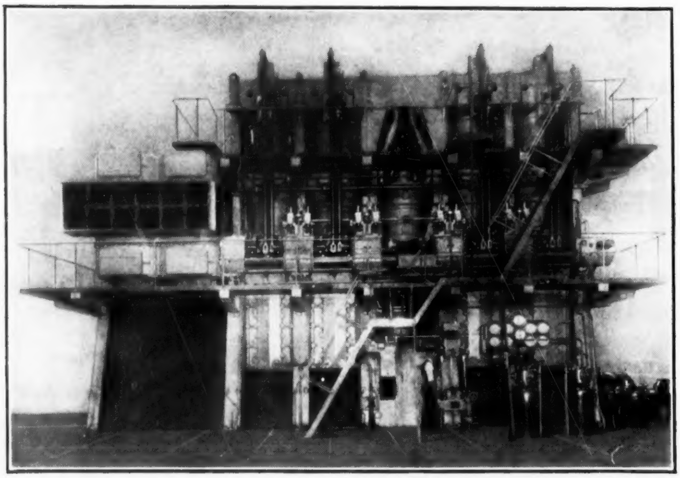
The Diesel engine has emerged out of a period of experimentation to a place among power producers as a practical, efficient and economical type of prime mover. Diesel engines are being built today in sizes and powers which were thought improbable but a few years ago, and their adaptation covers practically every field of industrial, municipal, and marine service. On land, on sea, and in the air have its uses steadily and quickly increased. Today there is not one field of power generation and use that has not been penetrated by the Diesel—from the aeronautic engine to the large stationary engine of 15,000 B.H.P. The Diesel locomotive is making headway in capacities up to 1,000 B.H.P.; the Diesel railcar is an established vehicle, the aeronautic Diesel has been perfected, and the automotive Diesel is coming to the fore. The rapidity with which the development of the Diesel engine has progressed is a tribute to the skill and resource of modern engineering.

The development of the Diesel engine first progressed along marine lines early in the present century. At that time Diesel engines of 100 to 150 S.H.P. were the outstanding achievement, although even in those days large powers were being considered. Until recently the power of the Diesel engine, for land purposes, was comparatively small, and, generally speaking, most units installed are not much in excess of 1,000 k.w. While the first cost per k.w. was high, due to the multiplicity of units, the advent of the double acting two-cycle engine has altered this position.

Not only are larger powers available in this type of engine but the first cost, weight and space occupied per k.w. are all considerably less without in any way reducing the reliability or longevity. Defects sometimes cited against the older types of Diesel engines, and ones which were fully exploited by its antagonists, were the lack of reliability and the high cost of maintenance. These defects are not inherent in the present day Diesel and certainly cannot be lodged against it in the face of its much greater simplicity and its lack of vulnerable parts, such as exhaust valves, intricate cylinder covers, and high compressed air plant.

The development of the high-powered Diesel engine has been almost entirely confined to marine service, a field in which reliability is the

first essential. It must be assumed that engines which will satisfy the arduous marine conditions cannot but be satisfactory for land purposes on the score of either reliability or its corollary, maintenance. There is, therefore, not the necessity today to sub-divide the units as in the past and the tendency in the future will probably be toward a few large engines rather than a greater number of smaller engines. There are many who believe that the limit in the size of Diesel engines has not yet been reached and that the rapid advance made in the past is but an indication of what mechanical and engineering skill will produce in the next decade.



Courtesy of Hooven, Owens, Rentschler Company

Fig. 1—Side view of a 4000 B.H.P., 27 ½ in. x 47 ¼ in., two-cycle, air injection, marine type Hooven, Owens, Rentschler Diesel engine. Force feed lubrication is applied throughout and separate pump plungers are employed for each point of cylinder oil introduction.

The term "Diesel engine" as generally used, is applied to internal combustion engines that burn heavy liquid fuels correctly in their respective cylinders. The distinguishing features of Diesel oil engines are that the fuel vapor is not absorbed by air before it is admitted to the cylinder, and that no inflammable mixture of vapor and air is compressed preceding its ignition.

Diesel engines compress air alone and the heat of compression is used to ignite the fuel which burns by consuming the oxygen of the air in the cylinder, the engine transforming the heat energy into work. To facilitate and accelerate the burning of a liquid fuel, it must be vaporized, atomized, or intimately mixed with air immediately preceding its ignition. The full Diesel type of engine is capable of burning practically any grade of liquid fuel from kerosine to crude oils and it consumes about one-third as much fuel per unit of power developed as does the average heat engine of corresponding rating.

The Diesel engine differs essentially from practically all other devices working with gaseous or liquid fuels. It is in reality an internal combustion engine in contra-distinction to other gas and oil engines which are, strictly speaking, internal explosion engines. The Diesel engine requires no carburetor, hot points, bulbs, heating torches, electric plugs, or any other device to aid ignition. No electricity is used in connection with its operation. The Diesel principle is the ignition of fuel by heat of compression only.

The chief point which distinguishes the Diesel from other forms of the internal combustion engine is the injection of oil fuel into a charge of air, which has been previously compressed by the rising of a piston, corresponding to a temperature sufficiently high to insure immediate ignition of the fuel. The fuel is forced into the cylinder by a blast of high pressure air coming from an air compressor.

There are numerous oil engines manufactured here and abroad which, while using a fairly high compression, sufficient to secure ignition of the fuel, do not operate on the Diesel cycle, but on what is a combination of combustion at constant volume (The Otto cycle) and at constant pressure (The Diesel cycle). These engines, familiarly known as "solid-injection" engines, do not make use of an air blast as the means of oil injection, but depend, instead, on a direct pump action. Such engines, however, are commonly referred to as solid-injection Diesel engines. As yet, comparatively few large engines function with airless-injection, although their number is increasing. The all important problem of causing the fuel spray to mix intimately with the fuel air in this type of engine is difficult as combustion not only depends upon the efficient atomization of the charge by the sprayer, but also on its penetration and distribution throughout the combustion space.

The features characteristic of the Diesel engine are:

(1.) Compression sufficient to produce the temperatures requisite for spontaneous combustion of the fuel.

(2.) Injection of the fuel by an air blast, or directly by pump pressures.

(3.) Combustion with practically no change in pressure from the maximum compression pressure; an absence of pronounced explosive effect.

The Diesel engine may be of either the four-cycle type or the two-cycle type. Practically speaking, these terms imply the number of times the piston must travel from one end of the cylinder to the other in order to complete the combustion of one charge of fuel. It would be more exact, therefore, to refer to such engines as four-stroke-cycle, or two-stroke-cycle respectively. Common usage, however, has abbreviated them to the terms four-cycle and two-cycle, the matter of strokes being understood as implied.

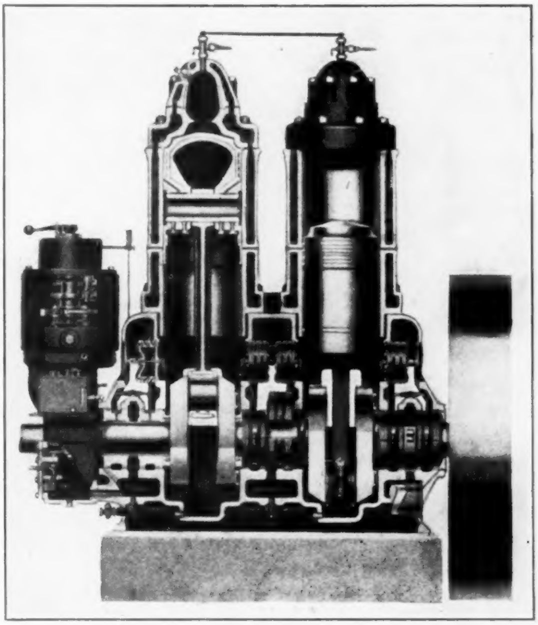
Such engines are built either as trunk-piston, or as crosshead type. In a trunk-piston engine the connecting rod is connected directly to the wrist pin in the piston and the side thrust, caused by the angularity of the connecting rod, is taken by the piston bearing against the cylinder wall. A crosshead type engine has its connecting rod attached to a crosshead traveling in guides, which crosshead in turn is connected to the corresponding piston. The side thrust caused by the angularity of the connecting rod is taken by the crosshead and guides.

Diesel engines may be separated into stationary, marine and locomotive engines, according to the service. While there are broad differences in these three classes, yet a number of engines can be adapted for these various services, with special alterations, such as, in the governor arrangement, flywheel, and fuel control. Such engines are also classified as to design, viz.: horizontal and vertical; single-acting, double-acting and opposed-piston type; slow, medium and high speed.

ESSENTIAL LUBRICATION CHARACTERISTICS

Lubrication of Diesel engines and its relation to the development of maximum power with a minimum of fuel consumption requires the careful attention of all owners and operators. The fuel, of course, is essentially the factor which makes the Diesel engine run, but the selection of the correct lubricants which must be employed to keep it running is of equal, if not greater, importance. Regardless of whether a lubricant is to serve the engine cylinders or is to be used on the air compressor or bearings, certain basic characteristics are necessary, viz.:

1. It must be so carefully refined as to be able to withstand the usual stresses and strains of intensive service. Also it should be carefully fractionated, or the lighter components so effectively removed that it will not be so volatile as to require an undue quantity to maintain a suitable lubricating film especially on the cylinder walls.
2. It should have as low an emulsification tendency as possible due to the contact with water which may occur. Filtration and very careful refinement will overcome this tendency.



Courtesy of Venn-Severin Machine Company

Fig. 2—A gear-driven pump circulates the oil under pressure to all main bearings, also to the force-feed lubricator which lubricates the cylinder, connecting-rod bearings, and the entire governor mechanism of this Venn-Severin Machine Co. Diesel engine.

3. It must be suited to the engine and also to the lubricating system installed; for one can readily appreciate that an oil might easily be an excellent lubricant, yet refined in such a manner as to be absolutely unsuitable for Diesel engine service.
4. Furthermore, it must be of such a viscosity or body as to maintain a lubricating film of suitable thickness between the wearing surfaces, under the prevailing temperatures of operation. Yet it should never be so heavy or viscous at these temperatures as to give rise to abnormal internal friction within itself, for this might readily develop excessive operating temperatures especially on the engine bearings.
5. It should be sufficiently adhesive to resist being squeezed out from between the wearing surfaces when subjected to the normal pressures of operation.
6. It should not congeal at any of the lower temperatures to which it might be subjected during storage or operation. In this connection the pour test should be low

enough to avoid the necessity for ever heating the storage tanks.

7. It should be capable of spreading readily over the wearing surfaces in the case of cylinder walls, not remaining in streaks or blotches whereby suitable sealing of the pistons might be impaired.
8. It must show as little carbon residue as possible, inasmuch as the decomposition which will occur when the oil is exposed to the intensive heat of combustion will, in the case of many oils, develop a large amount of objectionable carbonaceous residuum. Furthermore, this latter should be capable of easy removal.

It is fully appreciated that for an oil to meet all the above requirements the most careful attention is necessary, not only in refining but also in transportation, storage and handling in the plant. The very best judgment is necessary in the selection of the ultimate oil, taking into account, of course, those requirements which in the particular case are most desired.

LUBRICATED PARTS

In the absence of mechanical deficiencies, an engine will perform more satisfactorily and for a longer period of time when it is effectively lubricated. Conversely, the best of design will be of little avail in lengthening the life of an engine if the quality of a lubricant and the method of its application are not properly studied. This subject has always been of great importance to all Diesel engine manufacturers. In order to maintain efficient lubrication the operating factors which impose certain duties upon the oils, as well as the various lubricated parts of the engine must be considered.

Cleanliness of design, simplicity, and ready access to all parts are the fundamental requirements which have to be met by the builders of modern Diesel engines. These factors include a thorough, and yet as little complicated as possible system, or systems of lubrication, to assure complete service of oil to the various parts. On most Diesels similar lubricating systems are employed, different in detail according to constructional conditions of the machine.

The trend in Diesel design is to mechanically lubricate every part and to obviate entirely the hand oil-can. Some manufacturers are building engines which are entirely automatic in their lubrication, while on those engines where some hand oiling is required this has been limited to such parts as the valve gear, cam rollers, fulcrum levers and governors.

For the purpose of analysis it is practical to classify the several parts of Diesel engines requiring lubrication into the following groups:

1. Power Cylinders

Cylinders of small high speed Diesel engines employing trunk pistons are sometimes lubricated by the splash method whereby oil is thrown from the bearing systems. The crosshead type, and the larger trunk piston engines have their cylinders lubricated by mechanical force feed lubricators which can be adjusted to deliver a uniform quantity of oil at a regular rate of feed.

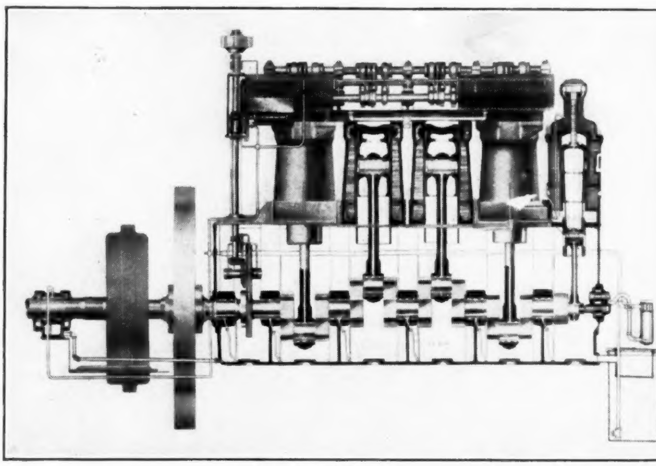
2. Bearings

The connection rod bearings, crank pins, piston pins, and main bearings are usually pressure lubricated by one grade of oil throughout. The main bearings of some engines are ring oiled while on smaller units the splash system may be employed.

3. Air Compressor Cylinders

The air compressors of air injection Diesels are lubricated by means of mechanical force feed lubricators.

Diesel engine lubrication must be positive, and capable of functioning under sufficiently high pressures to withstand the opposing operating pressures. For example, in the air compressor of a full Diesel engine this would be very high, even though the oil may be delivered at a time when the pressure exerted on the piston is lowest.



Courtesy of Worthington Pump & Machinery Corporation

Fig. 3—Longitudinal and sectional view of Worthington four-cycle air injection Diesel engine showing details of lubrication system. One grade of lubricant is used throughout for the bearings, power cylinders, and air compressor. Bearings and gears are pressure lubricated by a geared pump, driven from the main crank shaft.

Selection of Lubricants

Probably no other type of machine can be damaged so easily and quickly by faulty

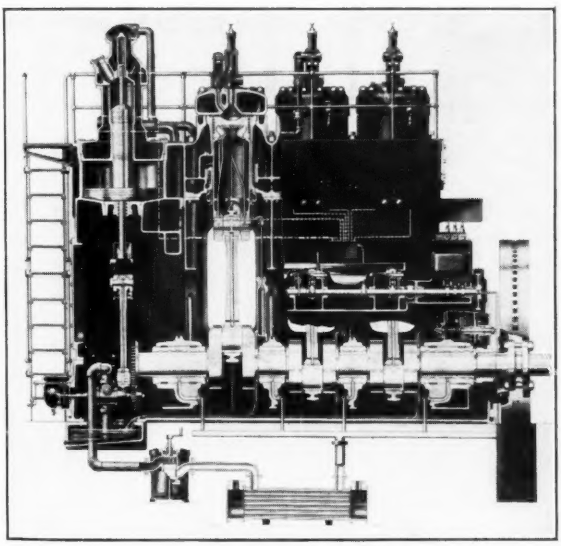
lubrication as the modern Diesel engine. While the average cost per unit to lubricate any Diesel engine is small, this cost can very quickly be increased beyond reason by using the wrong grade of lubricating oil.

In an oil engine the following lubricating demands are to be met:

1. High rubbing velocity with moderate pressures, i.e., main bearings and crank pins.
2. Low rubbing velocity with high pressures, i.e., wrist pins.
3. Low pressures with intense heat, i.e., pistons and cylinders.
4. Miscellaneous relatively small parts lightly loaded as a rule, but requiring a complexity of feeds, i.e., cam shafts, rocker arms and auxiliary drives.

Also the materials moving one upon the other differ widely. This range of pressures, speeds, temperatures, and materials would seem to require half a dozen different oils, which is obviously out of the question.

In many Diesel engine plants from two to four lubricating oils of different viscosities are being used to lubricate one type of engine. Recent tests have indicated that this condition in numerous cases can be eliminated, especially on small sized engines. Actual experience has proven that a lubricating oil may be suitable for the power cylinders, and yet



Courtesy of Nordberg Manufacturing Company

Fig. 4—Showing the oil circulating system on the Nordberg Diesel engine. Dotted lines show mechanical lubrication of power and air compressor cylinders. Bearings are pressure lubricated.

not have a viscosity so high as to preclude its use on bearings. The same oil may also be suitable for air compressor use where solid injection is not employed.

The selection of lubricants for a Diesel engine plant or a motorship should be strictly on the basis of quality, involving chemical characteristics to insure properly refined oils containing no impurities, and on viscosity, to insure proper grade. Neither oil color nor density signify as special properties in the selection of a lubricant. When light, medium or heavy oils are mentioned, it is the viscosity which is concerned. Light means low viscosity and heavy means high viscosity. Excessive friction may result from use of an oil of either too high or too low viscosity. Too high a viscosity will give a good film but the friction in the oil will be excessive. If the viscosity is too low the film may be broken. The physical characteristic viscosity is, therefore, of supreme importance in the selection of a lubricant as it is a measure of the ability of the oil to maintain the proper film under given conditions of speed, pressure and temperature.

Lubrication Systems

There are several systems commonly employed for the lubrication of Diesel engines, and often a combination of two or more systems are found on one engine.

On most Diesel engines there are two separate and distinct lubricating systems, which may be designated the high and the low pressure systems. The former comprises only the arrangements for supplying lubricating oil to the power cylinders and air compressor cylinders while the latter supplies oil to the various bearings throughout the engine. On some two-cycle engines a third system is used solely for lubricating the crosshead pins with oil under high pressure. A certain amount of hand oiling is also required, to take care of the small bearings, pins, etc., that require a relatively insignificant amount of oil.

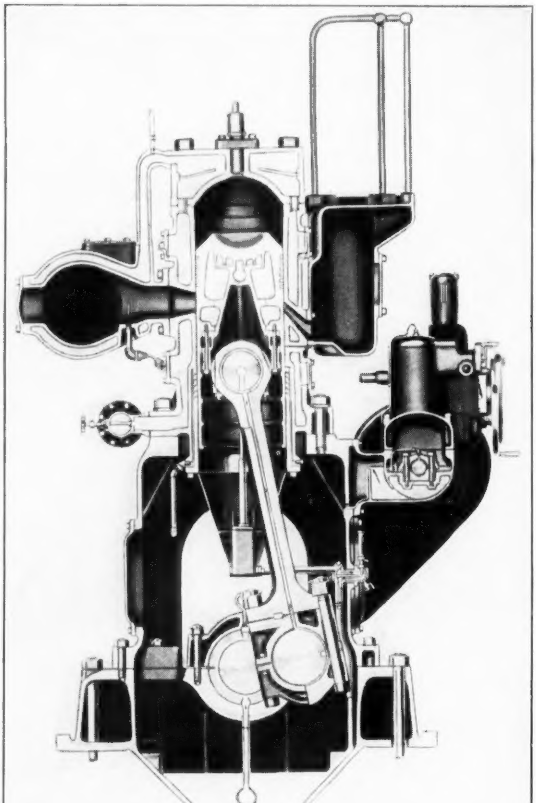
The manufacturers of Diesel engines equip their machines with oiling systems according to the type, size and number of revolutions. No one type is best for every service, although the force feed system is the general method. Other systems are known as the pressure circulation system, splash oiling, gravity feed, ring or chain oilers, and oil throw.

The various lubrication systems of Diesel engines may be grouped as shown:

	Cylinders	*Bearings*
1.	Mechanical Force Feed	Mechanical Force Feed
2.	Mechanical Force Feed (With oil throw)	Pressure Circulation
3.	Mechanical Force Feed (Without oil throw)	Pressure Circulation
4.	Mechanical Force Feed	Gravity or Ring Oiling
5.	Oil Throw	Pressure Circulation
6.	Pressure Circulation	Pressure Circulation
7.	Splash	Splash

POWER CYLINDER LUBRICATION

The problem of efficient lubrication of the power cylinders of Diesel engines is the furnishing and maintaining of an oil film on the cylinder walls under the existing conditions of grade of fuel, and the completeness of combustion, in



Courtesy of Fairbanks-Morse and Company

Fig. 5—Transverse section of a Fairbanks-Morse Diesel engine showing details of lubricating and cooling water systems.

conjunction with the other factors of high pressure, high temperature, fluid friction, and carbon formation. Successful Diesel engine cylinder lubrication is dependent on four factors, i.e.:

1. The use of properly refined oil.
2. Application of sufficient, though never excessive, amounts.
3. Delivery through oil ways so located that the piston and rings will receive the maximum of this charge.
4. Application at exactly the right time.

In order to secure the most effective lubrication of Diesel engine cylinders the oil should be delivered regularly to the cylinders and pistons by some form of Force Feed Lubrication, which will insure a charge of sufficient volume to cover the entire cylinder wall under the swabbing action of the piston.

Two Cycle vs. Four Cycle Lubrication

Irrespective of whether a Diesel is of the four-cycle or the two-cycle type there is little, if any, difference with respect to the lubricating oil best suited for their power cylinders. As some of the lubricant in a two cycle engine cylinder is usually scraped off from the piston and piston rings while passing the scavenging and exhaust ports, the oil consumption is generally slightly higher than that of a four-cycle engine of equivalent cylinder size. Too great an oil feed with two-cycle engines is frequently a contributing cause of excessive deposits in the scavenging air ports and the exhaust ports.

In the four-cycle engine there is not the heat developed during operation, nor is the lubricant on the cylinder walls subjected to the high velocity and vaporizing action of the exhaust gases as in the two-cycle type. This is accounted for due to an absence of exhaust ports, the gases being discharged in a straight line direction via the exhaust valves in the cylinder heads. The difference in temperature of the four-cycle and of two-cycle engines is not, however, great enough to require special consideration in connection with cylinder lubrication.

Furthermore, in the four-cycle engine, the pressure on the moving parts is not always of the same intensity. Whereas it may be difficult to have the lubricating oil spread uniformly over cylinder liner surfaces when the piston rings are under pressure, yet in the four-cycle type of Diesel the pressure is relieved during the second stroke. As a result the oil is more readily spread over the cylinder liner and materially facilitates the sliding action of the piston and rings during the subsequent strokes of the cycle.

However, the cylinders of two-cycle Diesels are not difficult to lubricate if the design has been carefully considered. In fact, the cylinders are the only parts requiring more than usual attention from a lubricating point of view. This is due to the oil being subjected to high temperatures at more frequent intervals over each cycle and because a high velocity of the gases of combustion at the exhaust ports increases vaporization of the lubricant in this part of the cylinder. In order to reduce vaporization an oil of lower volatility could be used, but this probably would mean that a higher carbonaceous residue would accrue.

The large double-acting two-cycle engine requires special consideration as far as cylinder, piston and stuffing box are concerned because of the relatively large heat flow. Four cycle engines add the complication of an elaborate valve gear, though even when double-acting they do not have such severe heat conditions.

Piston Seal and Oil Film

The high pressure gases above the piston of a Diesel engine are only prevented from leaking between the piston and cylinder wall by properly fitted rings in conjunction with a suitable sealing medium in the form of a lubricating film. Although the metal surfaces of cylinders, pistons and rings are carefully finished and accurately fitted, leakage of gases cannot be prevented unless the small openings between the wall and rings are effectively sealed by a viscous fluid.

Metal surfaces rubbing one over the other will generate excessive heat and produce abrasion of the material unless the surfaces are separated and free motion permitted through the use of a suitable fluid medium. This results in high metallic friction being replaced by low fluid friction and provides an adequate lubricating film to seal the piston properly while minimizing destructive metallic friction.

The lubricating oil film must be maintained under two distinct conditions of operation, i.e., high temperature and high pressure. The higher the temperature of the products of combustion the hotter are the adjacent parts, and consequently the thinner the oil film separating the metal surfaces. The greater the gas pressure, the more difficult it is to maintain a lubricating film between the rubbing surfaces. The upper piston rings, especially, will be called on to bear the brunt of these operating conditions.

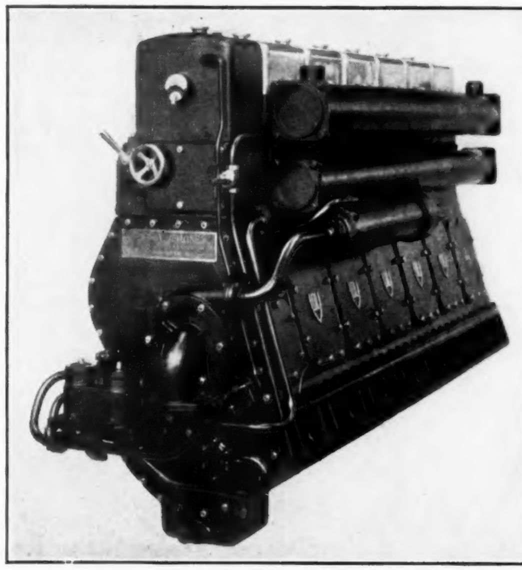
Effect of Temperature on Oil Film

A large portion of the cylinder wall over which the piston passes is swept by flame every stroke in a two-cycle engine, and every other stroke in a four-cycle engine. This flame starts out with a temperature of at least 2000 degrees Fahr., The maximum temperatures of the gases in Diesel engine cylinders range in the neighborhood of 2700 degrees Fahr., or even higher. If a lubricating oil film were exposed to such temperatures the lubricant would soon be burned away completely no matter how carefully the oil had been refined nor how high its flash point.

The maximum temperature decreases as expansion of the burning charge and exhaust take place. It gradually rises during the compression stroke. The minimum temperature is in the neighborhood of 250 degrees Fahr., while the average during a complete cycle is probably about 950 degrees Fahr. These temperatures refer to the gases, however, and not to the cylinder walls.

While experiments made with thermocouples placed close to the inner surface of cylinder walls, as well as in the heads of moving pistons, have revealed the temperatures at these points, yet it is practically impossible to obtain the actual temperatures of the surfaces. It is, however, assumed that the temperature increases rapidly as the inner surface of the cylinder wall is reached.

It is assumed that the cylinder walls have a



Courtesy of I. P. Morris and De La Vergne, Inc.

Fig. 6—A high speed four-cycle De La Vergne Diesel engine showing location of duplex oil pumps, filters, coolers, and sump tank. In this system one pump takes the oil from the sump tank to the storage tank, while the other pump takes the oil from the storage tank and delivers it through the filters and coolers to the bearings of the engine.

temperature of only about 30 degrees Fahr., above that of the circulating water. So long as the circulating water is not boiling it is safe to assume that the cylinder wall temperature is not above 250 degrees Fahr., and the temperature of the piston not many degrees higher. Therefore, with a proper cylinder and piston circulating medium the high temperature of the gases need cause no great concern.

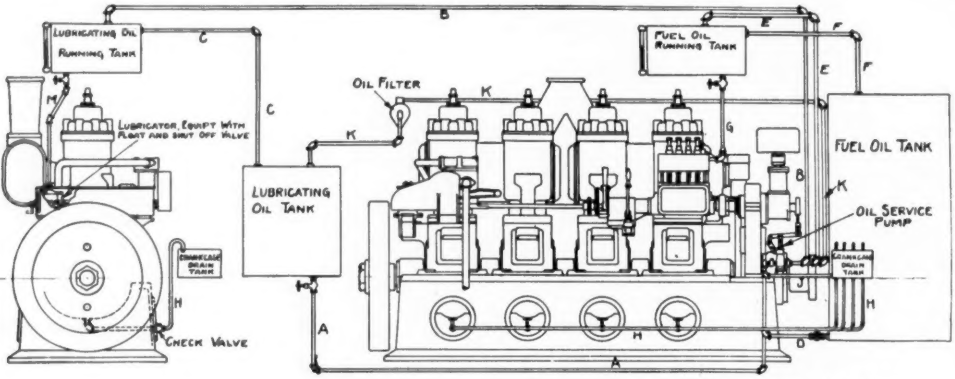
Most oils used for Diesel engine cylinder lubrication have a flash point higher than 350 degrees Fahr. Lubricating oil does not burn readily and furthermore the time in the cylinder is short. An engine running at only 100 r.p.m., would expose the lubricated surface of the cylinder to the action of the flame for less than one-quarter of a second. At higher speeds the time allowed for the oil to burn is so short that a flash point of probably 300 degrees Fahr., would be sufficiently high excepting under unusual conditions.

Because cylinders are adequately cooled by water or oil circulation through their jackets the walls are kept at a temperature which permits of their proper lubrication. Also, the time element in connection with the rapid reciprocating movement of the pistons furnishes intermittent protection and carries oil films

from the cooler parts to those subjected to higher temperatures. In single acting Diesels the highest cylinder wall temperatures are, of course, at the top and the lowest temperatures at the bottom. In double acting engines both ends of the cylinder have high temperatures, while the lowest temperatures prevail in the center. The operating factors on which the temperatures depend include the temperature, the velocity and the quantity of cooling water, the quantity of heat necessary to be conducted per unit of area through the cylinder walls, the diameter of the cylinder, the thickness of the liners, and the load developed by the engine.

Effect of Pressure on Oil Film

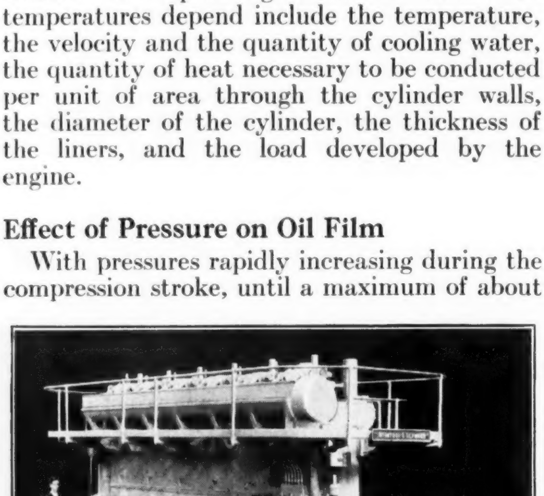
With pressures rapidly increasing during the compression stroke, until a maximum of about 500 lbs. per sq. in. is reached in the cylinders of a Diesel engine, it is the duty of the oil film to reduce leakage of the compressed gases to a minimum. The gases will tend to escape past the split of each piston ring as well as past the clearance between each ring and its groove. This causes pressure to build up behind the rings. The highest pressure is, naturally, behind the uppermost ring and is nearly as great as that on the piston head itself; it decreases gradually behind each succeeding ring until it is practically negligible behind the lowest ring.



Courtesy of Mianus Diesel Engine Company

Fig. 7—Line view of a Mianus Diesel installation showing location of principal fuel and lubricating oil accessories.

These pressures tend to force the rings, particularly those nearest the top of the piston, against the cylinder wall, producing a squeezing action which the lubricating oil film must support. The oil film is, therefore, dependent upon to support the pressure of the rings, while at the same time it must effectively seal them against blowby during the compression and power strokes.



Courtesy of McIntosh & Seymour Corporation

Fig. 8—A medium speed, four-cycle McIntosh & Seymour Corporation Diesel engine employing oil cooled pistons. A pressure lubrication system provides for the bearings, while a force-feed mechanical system furnishes the lubricant to the cylinders and air compressor.

Effect of Cylinder Size on Oil Film

The influence of heat and temperature on the lubricating oil film in Diesel engine cylinders is also dependent on the size of the cylinders. With two cylinders of different diameters but equal mean effective pressures, the products of combustion will lose their heat less rapidly during the power strokes in the cylinder having the larger dimension.

Small bore cylinders are easily lubricated. Although the cylinder wall area increases only as the bore so that the heat conditions might not at first be considered serious for large bores, they do become more so as the size increases. This is borne out both by increased lubrication and cooling difficulties. The amount of heat liberated increases as the square of the diameter and the greatly increased heat effect is probably due to radiant dissipation of heat. This has been shown experimentally to be a very important factor in heat loss from the burning charge to the walls.

Combined with the unavoidable greater thickness of cylinder liners in the larger engine,

the temperature difference between the cooling water and the gases in the cylinder will tend to increase. Furthermore, the increased cylinder wall thickness tends to reduce the heat absorbed by the cooling water and, therefore, augments the temperature of the oil film. As the temperature of the oil film is greater with large cylinders than with small ones the former require the use of a somewhat higher viscosity oil for efficient lubrication.

Combined Effect of Temperature and Pressure

The high temperature of combustion in a Diesel cylinder occurs simultaneously with the high pressure. This combined action, especially under adverse conditions, will be very detrimental to the oil film which will tend to thin down; it will furthermore enhance loss of compression and excessive cylinder liner wear. This inevitably results in increased power and upkeep costs.

Under such conditions of high pressure and temperature the lubricant must be able to spread rapidly on cylinder walls and to replenish its own lubricating film. It must have film strength even when exposed to high combustion temperatures as well as the pressures to which it is subjected through the piston rings, and it must maintain a complete piston seal effectively under all conditions. Cylinder liner wear is generally greatest at the combustion ends of the cylinders where maximum temperatures and pressures exist. The wear decreases along the cylinder walls in proportion to the lower temperatures and pressures encountered during the power stroke.

Oxidizing Influences

Regardless of the base of crude oil from which lubricating oils are made, oxidation takes place after a certain temperature is reached. This is first noticed in the darkness of color, oxidation forming in oils undesirable molecules of asphaltines, the extreme of which is artificial asphalt, a black, sticky matter which has a very high coefficient of friction in comparison with that of the original oil. This oxidation takes place regardless of the care or methods used in refining these oils.

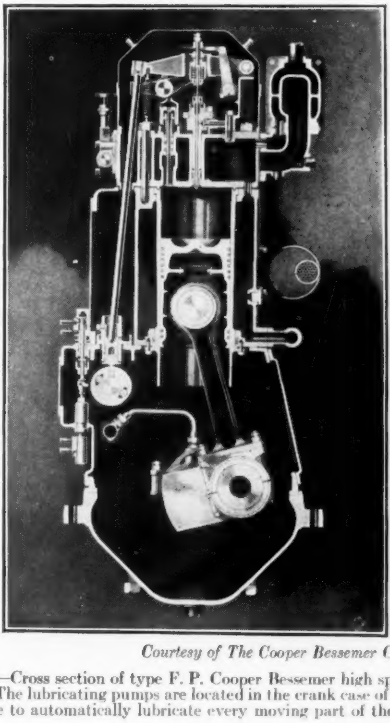
If the improper method is used for application of lubricating oils to the power cylinder, the oxidation of the oil is greatly increased, forming undesirable products in the new oil before it reaches the pistons. These undesirable products formed by oxidation increase friction, which results in a high cylinder liner and piston ring wear.

The necessary details to be considered in the control of oxidation of the oil are the arrangement of the lubricating oil piping, the lubricating oil injection tube in cylinders, the size of lubricating oil ports in the cylinder liner, and the design of the mechanical lubricator.

Points of Cylinder Oil Delivery

The number of points at which the lubricant should be applied to the piston will depend on the type and size of the engine. Two to four oil holes equidistantly located in the cylinder wall will generally suffice, although this will, of course, depend on the bore of the cylinder. They are usually located between the first two piston rings when the pistor is at its lowest point, although in some engines the oil supply points are found above such positions. One point of delivery is not considered as dependable due to the possibility of the opposite side of the cylinders being under-lubricated. In certain cases this can be obviated somewhat by cutting an internal groove in the cylinder wall at the point or points of injection for more even distribution of the oil.

Practical considerations of design may limit the number of points where the lubricant is fed



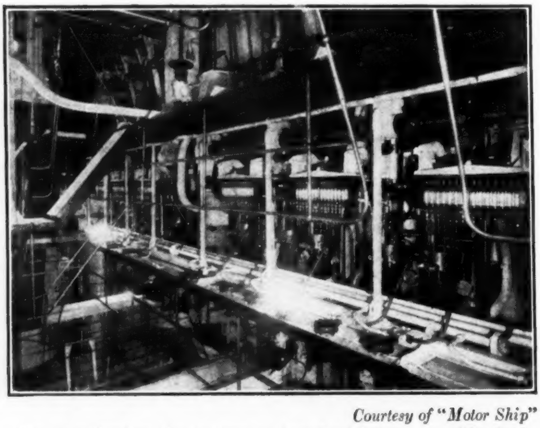
Courtesy of The Cooper Bessemer Corporation

Fig. 9—Cross section of type F. P. Cooper Bessemer high speed Diesel engine. The lubricating pumps are located in the crank case of the engine and serve to automatically lubricate every moving part of the machine.

to the cylinder but they should not be too far apart otherwise an excessive quantity must be introduced in order to furnish a sufficient lubricating film midway between the points of introduction. In the two-cycle engine, care is taken that none of these oil holes are located

in line with the exhaust ports, for otherwise the exhaust gases would tend to carry off a certain amount of lubricant which would be wasted.

It is now more or less standard practice to use a separate pump plunger of the mechanical lubricator for each point of oil introduction. This is desirable to insure positive lubrication and to obviate the possibility of one lead receiving more or all the oil due to difference in resistance at the end of the individual leads, which might cause cylinder scoring or even piston seizure.



Courtesy of "Motor Ship"

Fig. 10—Showing the battery of force-feed lubricators, sight feeds, and leads to the various parts of a four-cycle Burmeister and Wain marine Diesel engine.

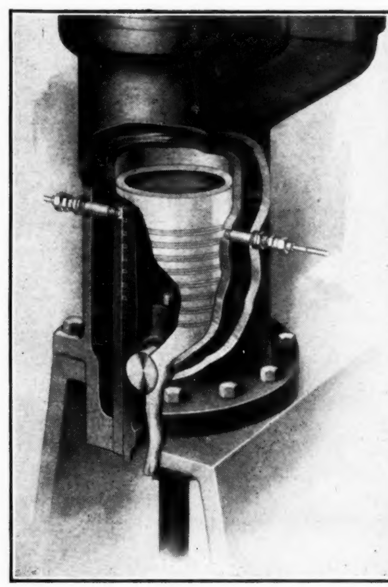
The exact location of the oil feed to the cylinders represents the manufacturer's idea of how lubrication is best accomplished. Some designers have even gone so far as to synchronize the time of lubricating oil delivery with the lowest position of the piston. The objective in all cases, of course, is the proper distribution of the oil over the whole cylinder wall surface subjected to rubbing contact, together with the attainment of the lowest permissible oil consumption. The comparatively large amount of wear which normally takes place on cylinder liners perhaps may be due to the fact that satisfactory lubrication of cylinder interiors is frequently difficult to attain.

Quantity of Cylinder Oil Feed

Fewer subjects are more frequently discussed in relation to Diesel engine operation than that covering the amount of lubricating oil necessary for efficient cylinder lubrication. No general figure can be stated, as this is dependent upon such factors as the type and construction of the engine, grade and quality of the oil, the method of application, the number of oil feeds and the kind of lubricant employed. While certain figures based on a definite number of drops per minute could be quoted, dependent upon ideal operating conditions, it is still very desirable that a certain amount of experimentation be carried out for practically every oil will vary in its lubricating ability, according to its viscosity and manner of refinement.

Oil engine operators should always be guided by the recommendations of the manufacturers of each type of engine, and by their own close observation of the condition of the engine cylinder walls, so they can gradually reduce the amount of lubricating oil to the most economical degree. Where a mechanical force feed lubricator is used, capable of feeding oil in synchronism with the strokes of the pistons it is frequently possible to control the oil feed so accurately as to approximate the theoretical requirements of the engine for the particular oil in service.

While cylinder lubrication is often carried out separately, with engines of the enclosed crankcase splash-oiled type, a certain amount of lubrication will be derived from the vaporous fog of lubricant which is present in the crankcase during operation. Naturally this should justify a certain amount of reduction in the oil feed to the cylinders themselves. The extent to which secondary cylinder lubrication of this nature is brought about, however, is not measurable with any accuracy; therefore, the amount to which cylinder lubrication could be



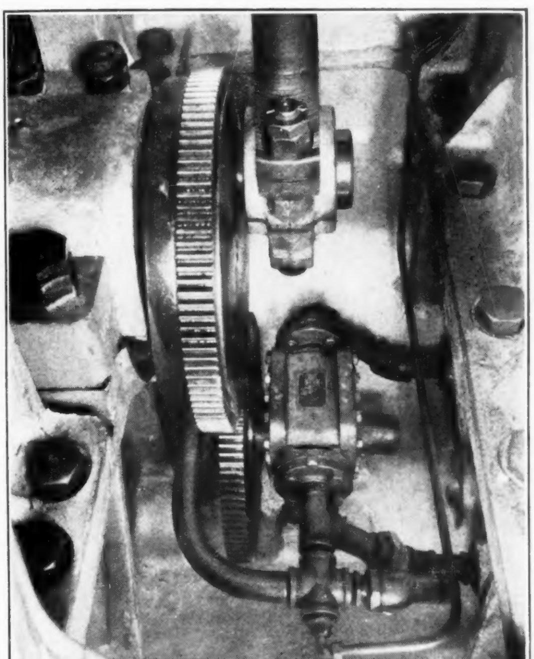
Courtesy of S. F. Bowser and Company, Inc.

Fig. 11—The number of points at which the lubricant should be applied to the piston of a Diesel engine depends upon the type of engine and size of cylinders. Usually two to four points of application equidistant in the circumference of the cylinder wall will suffice, although on larger Diesel engines the points of cylinder oil introduction will increase in number.

reduced cannot be definitely stated. It must be remembered that wherever the crankcase serves also as an air compressor, lubrication of the two-stroke cycle, splash-oiled engine has a potential tendency of requiring more oil in general than a four-cycle engine. Essentially this is due to the possibility of oil being blown out while in vaporous form during the scavenging period.

Experience has also shown that lubrication should be positive and uniform, otherwise rings will be worn and may even become stuck, with an appreciable loss in compression. The wristpin, for example, will also be affected. This part on certain engines will be subjected to relatively high temperatures, with but little opportunity for reducing this heat, unless it is cooled mechanically.

More attention should be paid to the condition of the oil film than to the quantity. The pulling of pistons and the finding of the cylinder walls well covered with an oil film is often misleading, because the oil may contain oxidized products that are detrimental to lubrication.

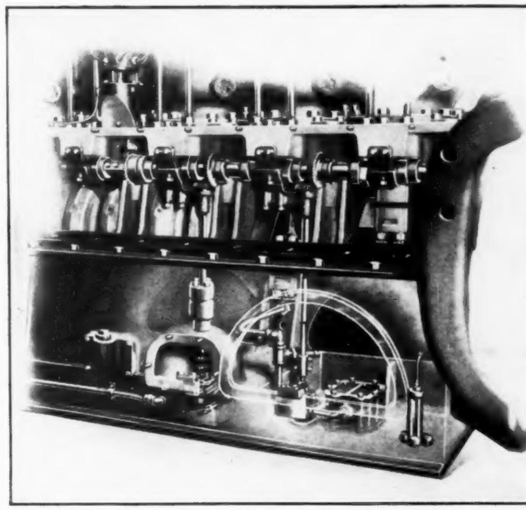


Courtesy of Busch-Sulzer Bros. Diesel Engine Co.

Fig. 12—A lubricating oil pump located in the crankcase of a four-cycle Busch-Sulzer Diesel engine. This is a positive pressure, gear driven rotary unit, designed to deliver oil to the main, crank, and wrist pin bearings under a pressure of from 10 to 12 pounds.

Using Heavy Fuels

When heavy fuels are burned the rate of lubrication to the cylinders must be increased. While figures regarding the per cent increase above that specified for normal Diesel fuels cannot be definitely stated, because of the many factors involved, yet they can be expected to vary from 10 to 30 per cent and higher above the regular consumption. Even with satisfactory combustion conditions trouble may arise with contamination of the piston lubricant by unburnt fuel. When very bad contamination occurs, some temporary im-



Courtesy of Ingersoll Rand Company

Fig. 13—View of Ingersoll Rand Company Diesel engine for locomotive service. The location of fuel oil and lubricating oil pumps and their driving mechanism are shown.

provement may be effected by syringing the piston and liner with kerosine, afterwards feeding with a copious supply of lubricating oil to preserve the oil film.

Such contamination may be avoided to some extent by giving immediate attention to the fuel valve as soon as any indication of dribbling, or faulty atomization becomes evident. Where a piston is in a very dirty condition the addition of about 20 per cent kerosine to the lubricating oil in the mechanical lubricator will assist materially in keeping the piston clean and avoiding piston grunting. Under such conditions the rate of oil fed to the cylinders must be increased to compensate for the reduced lubricating property of the lubricant.

Over-Lubrication

It cannot be too strongly stressed that excessive lubrication of cylinders is detrimental in the long run to satisfactory Diesel operation. In small high speed engines where cylinders are lubricated by oil thrown from the bearing system, operators have no control over the rate of feed. In such cases baffle plates and scraper rings are depended upon to prevent excessive quantities of the lubricant reaching the walls and over-lubricating them.

Even with the most suitable oil, over-lubri-

cation leads to abnormal carbonaceous deposits in the cylinder, which may clog valves or ports. As has been pointed out, this effect is more pronounced in the case of the four-cycle than the two-cycle engine, due to excessive oil being blown out through the exhaust ports of the latter type.

Effect of Carbon Deposits

Carbon deposits in the cylinders are only too frequently blamed on the lubricating oil, but in most cases care on the part of the engine operator would eliminate carbon trouble. Carbon exists in two forms.

1. Fine, free carbon suspended in the fuel and lubricating oils.
2. Chemical combinations in the form of hydrocarbons which go to make up the oil.

With fuel so regulated as to give a clear exhaust and by using only sufficient oil to lubricate the cylinder, carbon troubles will be reduced to the minimum. An over-lubricated cylinder will always cause trouble from carbon.

Such deposits eventually may restrict the area of the exhaust, thus preventing proper scavenging. This means that part of the residual combustion products will occupy some of the volume which properly should be occupied by fresh air. This will, obviously, lower the volumetric efficiency. The result will be that cylinder temperatures may rise, lubrication will be impaired, wear will be increased, seizing of the pistons and loss of power may occur and there will, of course, be excessive lubricating oil consumption.

Excessive deposits in piston ring grooves are a common cause for improper functioning of the rings. Such deposits result in blow-by of the gases, the destruction of the oil film, and excessive wear of both rings and cylinder liners. Deposits collecting on valve seats and spindles are directly responsible for leakage and loss of power.

Importance of Piston Ring Fit

The effective distribution of a lubricant in a Diesel engine cylinder will depend to a certain extent on the fit of the piston rings. Loose rings not only decrease the effectiveness of a lubricating oil, but also cause a loss of compression and of power by allowing blow-by to occur. The loss of compression and passage of hot gases which will result naturally tends to cause overheating of the lower parts of the cylinder and piston, the oil film being either burned or dried up prematurely. Fortunately, however, there is not the same opportunity for dilution of the lubricating oil occurring as exists in the carburetor type of engine, due to the fact that fuel charge is burned to practical completeness as fast as it enters the combustion chamber.

On the other hand, where the rings are too tight a scraping action will be exerted over the cylinder walls, the lubricating film often being broken or at least dangerously reduced. To counteract this possibility certain authorities advise slight beveling of the upper edges of the top piston rings in order to facilitate their sliding over the oil film on the up stroke.

Tight, improperly set rings may also lead to the seizure of pistons, especially where the lubricating film is not perfect, where an excessive amount of oil has been supplied or, in case imperfect combustion is occurring. With certain grades of oil an excess of this latter will develop gummy residues due to their lack of free-burning characteristics. While the engine is hot, naturally these residues will be relatively pliable, though in all probability extremely viscous. On shutting down, however, they will often congeal to such an extent as to practically seal or freeze the piston to the cylinder, rendering subsequent starting a difficult proposition.

Unusual conditions may cause a collection of residue around the piston rings to such an extent that removal of the piston from the cylinders is made difficult. Upon removal the pistons may have the appearance of solid, cylindrical plugs, owing to the ring's being embedded in what appears to be hard carbon. Attempts to remove the rings by any of the usual means will undoubtedly cause breakage, but if the flame of a small burner is played on the piston a few moments the deposit will soften up and the rings will spring free, permitting easy removal in the usual way.

[*Continued in February Issue.*]

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